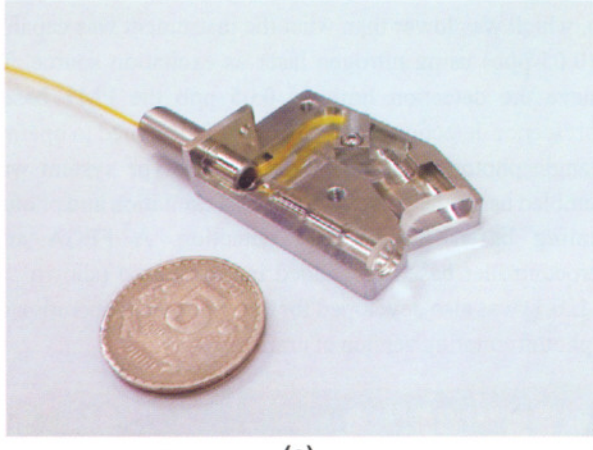
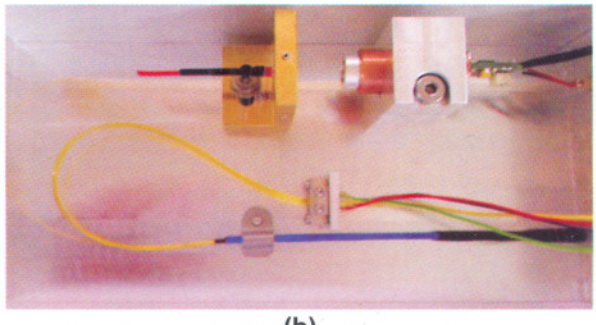
L.5 : Development of fiber-tethered sensors for use in radiation environments

During the XII Plan Laser Instrumentation Laboratory, Laser Biomedical Applications and Instrumentation Division has taken up design and development of optical fiber tethered laser sensor systems for remote inspection and metrology in high radiation environments. It is relatively easier to design and build a radiation-hard optical system than an electronic system. The sensor heads are designed with only optical elements and are connected to a remotely located (outside the radiation environment) electronic sub-system via a suitable optical fiber tether. This ensures that the sensor head can be used in a radiation environment without the worry of radiation damage to the sensitive electronic components. These fiber-tethered sensors should aid metrology and inspection of highly radioactive components such as spent fuel, inside hot-cells etc and reduce dose to operators during the course of measurement and inspection. As the sensor heads are miniaturized the waste generated due to decontamination or end-of-life from the use of these sensors will also be minimized.

As a first step in the development of various fiber tethered laser sensor systems, a fiber-tethered triangulation sensor has been designed and developed for non-contact profiling applications in hot-cell environment. A triangulation sensor is a non-contact position sensing system. It uses a laser beam to illuminate the object whose position is to be sensed and using an off-axis imaging system re-images the illuminated laser spot onto a Position Sensitive Detector (PSD). From the output of the PSD the location of the illuminated laser spot is determined. The fiber-tethered version of the developed probe head has no active opto-electronics components and consists only of optical components fabricated using fused silica for radiation hardness. The active sensing parts (Position sensitive photodiode and signal conditioning electronics) of the probe are in a remote box interfaced using a suitably designed fiber tether. The sensor head consists of a fiber collimating and focusing optics which generates the illuminating laser spot on the object to be sensed and a coherent optical fiber bundle (ribbon) consisting of eight optical fibers of 200 micron assembled in a row. An off axis optical system collects scattered light from the laser illuminated object and images it onto the input face of the coherent fiber bundle. The fabricated sensor head with the top cover removed is shown in figure L.5.1(a). The laser spot focusing lens and off-axis imaging lens can be seen along with the fiber bundle. The fiber attached to the collimating and focusing optics and the coherent optical fiber bundle are carried through a "heliflex" flexible SS sheath for protection and terminated in the remote box (shown in Fig. L.5.1(b) where the opto-electronic components and signal conditioning electronics are located. The output of a 2 mW, 635 nm laser diode is coupled to the optical fiber attached to the collimating & focusing optics and the coherent optical fiber bundle is butted to a PSD. This design ensures that the triangulation probe head is radiation hard and can be used in radiation environments such as glove boxes for inspection and metrology. The developed sensor probe has a resolution of 25 micron and a measurement range of 5 mm. It can be used to replace LVDT based position sensors in profiling applications. As the probe has only optical components and is connected to the remotely located electronics via an optical fiber tether it has the added advantage of being insensitive to electro-magnetic interference also.



(a)



(b)

Fig.L.5.1.a). The fiber tethered triangulation sensor with the top cover removed. The sensor head contains only optical components fabricated in fused silica and no electronic components. b). Inside the remotely located box the output of a laser diode is coupled to the optical fiber attached to the collimating & focussing optics and the coherent optical fiber bundle is butted to the position sensing photodiode.

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